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A NEW LOOK AT THE SPECIFICATIONS FOR FEDERAL GEODETIC CONTROL

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A NEW LOOK AT THE SPECIFICATIONS FOR FEDERAL GEODETIC CONTROL

Robert H. Randall,[1] M. ASCE

For many years, each Federal map-making agency developed its own standards for map control. To the extent that these were known outside of the Government, they were used by engineers and surveyors throughout the country. The Federal Board of Surveys and Maps, established in 1903, recognized the need for uniform standards and made studies to that effect. In 1933, the Board issued "Specifications for Horizontal and Vertical Control," which, without significant subsequent change, have guided the thinking and procedures of the Federal agencies up to the present date.

Since 1933, many occasions have arisen to question these standards. At that time, control was considered to be almost exclusively the tool of the topographer. Subsequent military demands in the guided missile field and the general adoption during the last twenty years of the use of the state plane coordinate systems as the tools of the land surveyor and the construction engineer have brought about new requirements; and the development of radically new types of instruments has presented the opportunity for improvements in methods with resultant increases in accuracy and efficiency.

Early this year, under the sponsorship of the Bureau of the Budget, an interagency committee, with membership from the principal Federal mapping agencies, was established to review the standards and their applicability to modern requirements and methods. This committee met on numerous occasions and, after much serious study by subcommittee groups and staff specialists, finally agreed on a preliminary draft of new specifications. This preliminary draft has been circulated to all interested government agencies, to the American Congress on Surveying and Mapping, and to the American Society of Civil Engineers. A final draft will be prepared and published after assembly and consideration of all comments received.

The most noticeable overall changes are: the introduction of a new high-accuracy order of control, the establishment of specific standards for fourth-order control, and the introduction of the fifth-order category for non-standard or sub-standard control executed for a single specific purpose.

The new specifications for first-order triangulation requires the length-checks on base lines to be twice as accurate as the 1933 standards. The discrepancy must not be less than one part in 50,000. The specifications for triangle closures (1 second average, 3 seconds maximum) have not been changed, but modern instruments make it possible, with standard observing routines, to stay well below the maximum allowed and thus achieve the higher prescribed accuracy in length.

The new category of "Improved Second-Order" triangulation roughly corresponds in length-check requirements to the old first-order. The discrepancy must not exceed one part in 25,000. Triangle closures may average

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1.5 seconds with a 4-second maximum. In methods and requirements it does not vary greatly from first-order.

The new second-order triangulation specification is the same as the 1933 version in length-check and triangle-closure requirements; one part in 10,000 with 3-second average and 5-second maximum triangle closures. Third-order is similar; one part in 5,000 length-check, with 5-second average and 10-second maximum triangle closures.

Fourth-order triangulation is not classed as geodetic control, need not be monumented, and should not be extended beyond the needs of the particular project for which it is established. Length-check is one part in 2,500; triangle closure 15-second average, 30-second maximum.

Fifth-order control is less accurate than fourth-order and should only be used when it has been determined to be of sufficient accuracy for a particular intended purpose. It should not have errors of position that are discernable at map publication scale. Graphic, mechanical, or optical methods, or any combination of these, may be used for fifth-order control.

In addition to the basic requirements related above, subsidiary requirements have been introduced that are further indications of the quality of the work. These include specifications for: strength of figure (both for total figure between bases and for single figure), actual and probable error of base measurement, side-checks in length for a single figure, and accuracy of astronomical control azimuth. Another new concept, limiting indiscriminate extension of lower-order control, is the statement of maximum allowable position error, ten feet for third-order, and twenty feet for fourth-order control, referred to the local datum as defined by high-order positions in the area.

A similar set of specifications re-defines the limitations in terms of position determination by traverse. The same five orders of accuracy are used. Most of the basic definitions of closure in terms of length of traverse are preserved—1:25,000 for improved second-order, 1:10,000 for standard second-order, 1:5,000 for third-order, and 1:2,500 for fourth-order, but a change has been made in the first-order requirement, where 1:35,000 is specified. A new concept introduced in the accuracy requirements for traverse is an additional statement of the allowable error in terms of a constant times the square root of the length of the traverse in miles.

This type of specification has long been used with levels, is consistent with the mathematical probability of compensation of accidental errors, and tends to restrict the toleration of large errors in long traverses. Such large tolerances, permitted under a straight proportional specification, may obscure evidence indicative of rather large blunders. The new specifications are so arranged that the straight proportional tolerance is more restrictive at traverse lengths of less than ten miles, and the exponential tolerance is more restrictive at traverse lengths of more than ten miles. The more restrictive specification is to be applied in each individual case. Another important specification, introduced in the new series, states the permissible closures between fixed azimuths. This specification is also dual, providing a tolerance that is proportional to the number of stations up to a certain number, varying with the order of accuracy, and is proportional to the square root of the number of stations if the line contains more than that number of stations. For example, for standard second-order traverse, the specification calls for an azimuth closure of three seconds times the number of stations, up to eleven stations, and ten seconds times the square root of the number for more than 11 stations. This latter closure results in two seconds per station at

twenty-five stations, which is the maximum number of stations permitted between check azimuths.

Other requirements state the number of courses between azimuth checks, the accuracy of astronomical azimuths, and the accuracy of taping. It can readily be appreciated that total error is the combination of azimuth error and distance error; hence, taping must be more accurate than the overall traverse accuracy. In these specifications, it is assumed that angles and distances are of approximately equal accuracies, in which event each must be approximately 1.4 times more accurate than the combined requirement.

These specifications are of the "performance" type, in that they state the results to be achieved but make no attempt to specify the methods to be used to attain the results. Some prominent experts on control maintain, not without some reason, that the methods used are just as important as the closure errors in the final evaluation of the results.

Another change from the 1933 specifications involves the recommendation for spacing of horizontal control stations. The use of geodetic control in property surveys and construction has brought about a demand for more stations, more closely spaced. As a result, the recommended spacing of first-order arcs has been reduced from 120 miles to 60 miles. The recommendations for spacing of improved second-order and standard second-order stations envision the placing of approximately one station for every 50 square miles which is equivalent to saying that no point will be more than approximately ten miles from a second-order station. This close spacing of second-order stations, together with the closer spacing and increased accuracy of the first-order stations on which they are based, should materially assist State and local governments, and engineers and surveyors in private practice, in the use of the National network of geodetic control.

Very little has been changed in the specifications for vertical control. The specifications for circuit or section closures for first-, second-, and third-order leveling remain identical with the 1933 requirements. For the first time, however, a specific statement is made for closure of fourth-order accuracy. Work of this accuracy is not to be permanently marked and is primarily to be used as supplemental control for topographic mapping where standard Federal practice requires control elevations to be accurate within one-tenth of the contour interval. As in the horizontal control specifications, the new vertical control is to be spaced at considerably closer spacing; the first-order lines at 60 miles instead of 100 miles, and the second-order at 7 to 8 miles instead of 20 miles.

What is the meaning and the expected result of these new specifications? First, it is obvious that, from now on, the stated accuracy of the basic Federal control network will be consistent with the practice, inasmuch as the first- and second-order triangulation of the U.S. Coast and Geodetic Survey has been conforming to these new accuracy specifications for a number of years. Because of this higher basic accuracy, and with the introduction of the closer spacing, the local datum as defined by the higher orders of triangulation will be much more rigid and the need for local readjustments to obtain consistency with high-accuracy, locally-established control will be rare. Second, as the closer spacing of basic stations becomes a reality rather than a paper specification, increased use of local geodetic control will be made by surveyors and engineers. It will be feasible for local governments and private surveying organizations to establish the local, on-site control as required by running short traverses or simple triangulation schemes, without involving the large and prohibitive expenses that are sometimes now required in the

establishment of local control between widely-spaced, inaccessible, and sometimes unrelated basic stations.

It is neither necessary nor germane to dwell on the value to the engineer, the surveyor, and local governmental agencies of the utilization of local control for preliminary and final planning, land surveying and subdivision layout, coordination of public utilities, land-use planning, zoning, development control, etc. Neither is it necessary to point out that, even though the basic control is established and computed by geodetic methods, the utilization of this control locally involves, through the use of the state plane coordinate systems, only the field methods and computing procedures of plane surveying. It is merely desired to emphasize, in conclusion, that the "new look" in Federal control is largely brought about by a desire, on the part of the Government, taking advantage of the availability of new instruments and procedures, to make the basic control, here'ofore established primarily for geodetic studies and mapping control, increasingly useful and available to the local engineer and surveyor, with a resultant "new look" in their practices in the form of more efficient planning and layout for construction and increased validity and ease of retracement of property surveys.

PROCEEDINGS-SEPARATES

The technical papers published in the past year are presented below. Technical-division sponsorship is indicated by an abbreviation at the end of each Separate Number, the symbols referring to: Air Transport (AT), City Planning (CP), Construction (CO), Engineering Mechanics (EM), Highway (HW), Hydraulics (HY), Irrigation and Drainage (IR), Power (PO), Sanitary Engineering (SA), Soil Mechanics and Foundations (SM), Structural (ST), Surveying and Mapping (SU), and Waterways (WW) divisions. For titles and order coupons, refer to the appropriate issue of "Civil Engineering" or write for a cumulative price list.

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c. Discussion of several papers, grouped by Divisions.

e. Presented at the Atlantic City (N.J.) Convention in June, 1954.

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